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The role of infectious disease impact in informing decision-making for animal health management in aquaculture systems in Bangladesh

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ABSTRACT

The aquaculture sector in Bangladesh is an important employer and a significant source of foreign exchange. In addition, it contributes significantly to food security due to the role of fish in peoples' diets, the most important source of protein and micronutrients. However, infectious diseases represent an important barrier to sector development due to economic losses and vulnerability of smallholders. The aim of this study was to gain an overview of the impact of infectious diseases in the aquaculture sector, and to assess the usefulness and use of impact studies in decision making for animal health management and biosecurity governance in Bangladesh. A review of scientific and grey literature on infectious disease impact in different aquaculture systems was conducted and their methodologies and findings summarised. Subsequently, interviews with 28 stakeholders from the private and public sector were conducted to enquire about decision-making structures in animal health management. The data were analysed using the framework method to allow the development of themes, by using the information, experiences and opinions inductively obtained from interviewees, deductively through the reviewed literature. Results showed a substantial socio-economic impact of infectious diseases. The numerous stakeholders involved in the decision-making process explained that key barriers to effective aquaculture health management were insufficient resources to investigate and tackle infectious aquatic animal diseases, a dearth of legislation and capacity for disease surveillance, a reliance on reactive response, and a lack of impact and evidence-based approaches for prioritising problem-solving, commonly based on anecdotal evidence. Furthermore, communication among the multiple stakeholders involved was reported to be weak. This complex situation requires a multi-level response, which should span from strengthening the knowledge of farmers and professionals in the field to the improvement of surveillance and diagnostic systems. Improved systems along with evidence on disease impact could inform the prioritisation of diseases and resource allocation for disease control in Bangladesh. Further, this evidence needs to be used to advise decisions to have a true value, for which establishing and strengthening communication pathways and processes is critical to make systematic use of the information and improve animal health management. In the light of future threats to Bangladesh such as climate change, increasing population density and demand for animal source foods, it is crucial to strengthen animal health management systems to reduce livelihoods vulnerability, food insecurity and the likelihood of disease emergence.

1. Introduction

Bangladesh is highly suitable for aquaculture production due to the tropical humid climate and its geographical characteristics, in particular its system of around 230 rivers including multiple ponds and flooding areas (FAO, 2010). The fisheries sector is a significant contributor to the economy, and with a share of 4.39% of the GDP (FRSS, 2012) it is the second most important agricultural activity after rice production. In 2013 around 14.5 million people relied on aquaculture, of which 13.8 million on fish and 0.8 million on shrimp production. The fisheries sector overall employed 16 million people (Apu, 2014; FRSS, 2013). Moreover, it provides an estimated 60% of the

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protein intake in peoples' diets, equivalent to 18.1 kg per person per year, thereby constituting by far the most consumed animal source food (Apu, 2014; Belton et al., 2014; Bogard et al., 2015). Fish is an important source of micronutrients such as vitamin A, zinc and iron and thus contributes to alleviate the unsolved micronutrient deficiency problems in the country (ICDDR et al., 2013). Despite having achieved important development goals, food insecurity remains high in Bangladesh, leading to costs of USD 1 billion per year of economic productivity forgone due to malnutrition (Howlader et al., 2012).

Fish production in Bangladesh, classified into inland capture, inland culture in pond and gher[1] production, and marine fisheries, has expanded substantially in the past 15 years from a fisheries output of 1.6 million tonnes in 2000–3.3 million tonnes in 2012 (Apu, 2014). Initially, inland capture and inland culture had similar production shares in the aquaculture market with 40% each, but inland culture experienced a greater growth from 2000 to 2012 with > 160% vs 45% of inland capture (Apu, 2014). This was mainly due to an increase of domestic tilapia and *Pangasius* catfish production triggered by an increasing demand for these products.

The predominant aquaculture activities are pond-based finfish production and shrimp and prawn[2] production usually in gher and rice fields to produce fish during the seasonal flooding. The main finfish production in terms of volume and value generated comprises carps (a species that historically has characterised the aquaculture in Bangladesh), catfish and tilapia. Catfish and tilapia are exotic species known in the country for many decades but have only seen a significant increase in production since 2000; they now account for 29% of the aquaculture production (Belton et al., 2011; Ahmed et al., 2012). Due to the availability of pelleted feeds, the production of these two species was shifted towards more intensive farming with higher productivity and output, which increased accessibility and affordability. This production opportunity engaged many communities of the north and central regions of the country in diverse value chains activities, generated income and employment, and had a positive impact on nutrition by improving access to fish and vegetables (Ali et al., 2013; Ahmed et al., 2012). It has been argued that there is potential for higher production and there should be a shift towards the export markets given the emergence and expansion of commercial farms (Edwards and Hossain, 2010). However, this would require producers to comply with higher standards due to export regulations, which may affect price structures and national supply. Also, intensification of fish farming without provision of training to farmers and strengthening of animal health management would likely generate disease problems (Ali et al., 2013; Faruk, 2008).

Another important production is shrimp and prawn providing livelihood to almost one million people in the South of Bangladesh. Shrimp, and to a lesser extent prawn, represent the second most important export commodity next to textiles and was worth USD 422 million in 2013 (Debnath et al., 2014). The principal export markets are the European Union (EU) and the United States of America (USA) (GoB, 2015; Karim et al., 2012; Pollard, 2010; Rahman and Hossain, 2009). Shrimp culture has greatly expanded in the coastal areas of the country; the production area grew from 39,496 ha (ha) in the 1980s to 275,000 ha in 2014 (FRSS, 2015). This rapid, unplanned and unregulated expansion has serious social consequences due to uneven distribution of land and environmental impacts. Ecosystems have degraded and changes in salinity contribute to disease emergence and threaten livelihoods of vulnerable populations. Therefore, despite being a key economic activity for the country, shrimp culture is often regarded as an unsustainable practise that calls for sustainable interventions to promote resilience of the system (Afroz and Alam, 2013; Karim et al., 2006; Paul and Vogl, 2011; Rahman et al., 2013; Shahidul et al., 2011).

Diseases in aquaculture hamper production and cause economic losses. White Spot Syndrome Virus (WSSV) emerged in Bangladesh in 1994 and since then has been a major barrier to economic profitability of shrimp production (Chowdhury and Muniruzzaman, 2003). Moreover, the high density of farms, formal and informal trading practices in live aquatics, unpredicted climatic events, shift of ecological patterns driven by climate change, and multiple socio-political characteristics are shaping a complex environment for disease emergence, transmission and control (Deb, 1998; Hossain et al., 2013). In finfish production, several diseases have been described. Epizootic Ulcerative Syndrome (EUS) was first described in 1988 in Chandpur district and remains a problem in finfish farms. The severity and impact of the outbreaks is believed to have decreased over time (personal communication), but a systematic surveillance programme would be required to confirm this officially. With the introduction of catfish and tilapia and the associated intensification in commercial production, new threats emerged, such as streptococcosis in tilapia (Ali et al., 2013; Hossain et al., 2014). The occurrence of disease in aquatic animal systems is widely recognised to be linked to the environmental conditions and production factors (Kautsky et al., 2000; Le Moullac and Haffner, 2000) and animal health management plays a crucial role in the prevention and control of diseases. However, it has been described that farmers in Bangladesh lack training and knowledge about these aspects (Begum and Alam, 2002; Faruk et al., 2004; Faruk, 2008).

Decision-making for animal disease management is closely linked to the political economy that defines investments in animal health and drives factors impacting on intervention programmes, such as social and cultural acceptability (Rushton et al., 2007). Political strategies and cultural aspects often impact on the formulation of technical targets of disease mitigation, sometimes independent of economic criteria. In order to prioritise interventions to improve productivity and ensure food security and food safety, knowledge on the impact of infectious diseases is needed. Besides economic impact, it is also important to know how infectious diseases in these production systems affect the livelihood of producers.

The aim of this study was to conduct a literature review on infectious disease impact in carp, tilapia, catfish and shrimp production and to assess the usefulness and use of impact studies in decision-making for animal health management in Bangladesh. The objectives of the study were to gain an overview of the impact caused by infectious disease in aquaculture and to describe the impact assessment methods used, and to evaluate their usefulness for end-users by characterising the decision-making environment for animal health management. Finally, the results were interpreted to recommend how impact research can be made more relevant for decision makers.

2. Materials and methods

This study was conducted in two steps. First, a systematic literature review was performed to provide information about the disease impact in aquaculture systems and the methods used for the impact estimation. The sources of scientific literature were CAB Abstracts and Scopus databases, which cover around 91% of the journals related to veterinary topics (Grindlay et al., 2012). For this study, only articles written in English and published after 1995 were considered. The grey literature, comprising unpublished papers, reports or conference proceedings, were searched using the Google™ web search engine. Available pages were screened until three consecutive pages did not provide any further relevant results. The search terms used are listed in Table 1. Within each section, the terms were linked with the Boolean OR operator and the four sections were linked by the AND conjunction to generate search strings. To select the documents, the inclusion criteria applied were either quantitative or qualitative estimation of any form of impact

[1] A traditional agriculture system in Bangladesh obtained by digging a space into a rice field to use for fish farming, shrimp or finfish, while the extracted soil is used as dykes where vegetables are grown.

[2] In this study, we use the terms "shrimp" and "prawn", as it is used in Bangladesh. The term "prawn" is for freshwater crustaceans, commonly *Macrobrachium rosenbergii,* whereas "shrimp" is for brackish water crustaceans, commonly, *Penaeus monodon*.

Table 1
Search terms used in the review, combined to generate search strings.

Section	Search terms
Animal	animal*, fish*, food system*, poultry, bird*, avian, chicken, tilapia, catfish, shrimp, aquaculture, carp
Health	disease*, health, infection*, outbreak*
Impact	economic impact, economic loss, economic cost*, net cost*, direct cost*, indirect cost*, disease impact, nutrition impact, trade losses, production losses, livelihood loss, intervention costs, surveillance costs, prevention costs, vaccine*, drug, treatment, cull*
Country	Bangladesh

The symbol * was added to those terms in which suffixes can be added to form a word and are used in the search process in the databases to generate all the options from a same root. E.g. animal* = animal or animals; Fish* = fish, fisheries, etc.

(e.g. economic, nutritional, livelihood impact) on the aquaculture sector in Bangladesh. The reference lists of the publications included were screened for further relevant studies. Moreover, collaborators were asked to share relevant publications they were aware of. In addition, a list of all postgraduate theses produced in the Bangladesh Agriculture University (BAU), Khulna University and University of Chittagong were obtained by directly contacting these institutions. The same search criteria were applied, but the search was conducted manually. Subsequently, a list of common disease impact categories was compiled taking into account the biological impact of disease (e.g. mortality, reduced yield) and the impact due to reaction to disease occurrence (e.g. expenditures for vaccination or treatment) based on the framework proposed by Rushton et al. (1999). The impact categories included production losses, nutrition impact, public health impact, livelihood impact, trade impact, expenditures for disease management in the animal sector and the human sector, respectively, and a category called 'other'. All publications retained were read and the relevant disease impact information extracted. At the same time, the method used to estimate the disease impact was listed (e.g. cost analysis, gross margin analysis, cost-benefit analysis).

In a second step, semi-structured interviews were conducted with public and private decision makers from the aquaculture sector to characterise the decision making environment. A purposeful sampling approach was followed, by selecting interviewees expected to have direct involvement in aquaculture health management and related decision making, attempting to represent the main relevant stakeholders and organisations. The initial selection of participants was based on the advice of collaborators with expertise in aquatic health and on the documents reviewed. In addition, following a snowball sampling approach (Berg and Lune, 2012), respondents' suggestions about additional relevant stakeholders to be interviewed were considered. The interview guide covered the following topics: (i) decision pathways (people involved, procedures, roles/responsibilities, information flows) for investments in animal/fish health, (ii) description of key decision-criteria used to make investments into animal/fish health (e.g. legal requirements, expectation from trade partners, cost-benefit measure, zoonotic impact), (iii) consideration of the value of a production system in decision-making, (iv) consideration of disease impact analysis of a production system in decision-making, (v) constraints in decision-making and information needs. Ethical approval for the interviews was granted by the RVC's ethics committee (approval number URN 2015 1400). Before each interview, a brief introduction to the study was given and oral consent obtained. All interviews were conducted in English for convenience, with assistance of a Bangla speaker collaborator, facilitating discussion when required. However, English language was not a selection criterion for the interviews. All conversations were recorded apart from phone calls or if there was too much background noise; in these cases, written notes were taken instead. Given the heterogeneity of the interviewees in terms of level of seniority, technical expertise, institution, position and time availability, the questionnaire was used as guidance and the interviews held in conversation style applying relevant questions according to the interviewee's capacity and expertise. During the interviews, emerging key topics, gaps and limitations found in information were noted. These topics were discussed in subsequent conversations with other respondents when similar topics emerged in the conversation and were used as triangulation. Upon conclusion of the field work, all interviews were transcribed. While listening to the interviews, common themes across the participants were noted to produce an overview of decision-making processes and disease control issues at various levels. Subsequently, a more in-depth analysis was conducted guided by the framework method (Gale et al., 2013; Green and Brown, 2005). This approach allows the development of themes obtained inductively by experiences and opinions of participants and deductively based on reviewed literature. Transcripts were analysed and coded by describing the content and ideas as well as by adding pertinent notes about the context, interviewee tone, and linkages identified. Next, themes were identified following the sections of the questionnaire. Moreover, other recurrent themes that emerged were also described. Finally, data were charted and summarised for interpretation with the aim to understand the decision-making environment and to complement the literature review.

3. Results

3.1. Literature review

A total of 32 publications were obtained from the database screening, of which eight matched the inclusion criteria. Four additional publications were found through the reference list of the screened documents. Further 20 documents were provided by collaborators, of which three fulfilled the inclusion criteria. Finally, 15 studies were kept for the full text review; extracted information is summarised in Table 2.

All studies reported production losses, livelihood impact or trade impact. Finfish studies described the existence of multiple clinical pictures attributed to infectious and non-infectious causes often without a confirmed diagnosis. Symptoms like pop eye, ventral reddening, tail and fin rot, haemorrhagic lesion over body surface, dropsy, gill rot, white spot, and epizootic ulcerative syndrome (EUS) were found in various publications for finfish (Dey et al., 2014; Faruk et al., 2004; Hasan et al., 2013). Since its appearance in Bangladesh in 1988 until 1998–99 the economic impact (i.e. production losses, income losses, price fall) of EUS in carp and wild species was described in multiple studies (Arthur and Subasinghe, 2002; Brown and Brooks, 2002; Khan and Lilley, 2002; Lilley et al., 2002). One study described livelihood impacts of carp disease, such as the reduction of the total average yearly income of 18.5% during an outbreak of EUS in 1999 (Brown and Brooks, 2002). Later studies in carp polyculture production reported a prevalence of EUS similar to other clinical syndromes such as dropsy, fin rot, gill rot and observed that production losses were stabilising (Dey et al., 2014; Faruk et al., 2004; Hasan et al., 2013). *Streptococcus* spp., was isolated from tilapia that suffered a mass mortality episode of 80% during a disease outbreak in 2007 at cage level. It was hypothesised that these problems were associated with poor management and high stocking densities. Other diseases in finfish were described to have multiple and/or unspecified aetiologies and many diseases seemed to occur simultaneously in the study areas. Finfish mortality was often unclassified due to the limited diagnostic support (Khan, n.d.).

In shrimp production, WSSV was described to be a major threat, causing significant production losses. Production levels fell from 500 kg/ha in 1980s to 100 kg/ha after the emergence of the virus in the year 1994 (S. M. N. Alam et al., 2007). In 1996–97 a major outbreak caused significant losses in the Southwest of Bangladesh; the area where most of the production is located. Another major outbreak in

Table 2
Economic impact of disease reported for aquaculture species in Bangladesh.

Ref.[a]	Disease/ hazard/topic	Year(s) study focuses on	Area covered – studied species	Production losses	Price impact/Livelihood impact/Trade impact/Mitigation costs: for private sector/for public sector	Public Health impact and others
Arthur and Subasinghe (2002)	Epizootic ulcerative syndrome	1988–89	General	Economic losses due to EUS were estimated at US $3.38 million during the first outbreak and US$2.24 million during the second occurrence.	Drop in demand and supply of fish by some 64.5%, with prices falling 50–75% in badly affected districts	Impact on biodiversity: pathogens are likely to determine aquatic community structure and regulate host abundance
Brown and Brooks (2002)	Epizootic ulcerative syndrome	August–Sept. 1999	Six districts in Bangladesh (Rajbari, Madaripur, Bogra, Lakshimpur, Feni and Comilla)	.	Losses due to fish disease made up, on average, 3% of the total on-farm income (US$31), = 18.5% of the total average yearly income from fish production	
Khan and Lilley (2002)	Epizootic ulcerative syndrome	1998 – 99	64 districs in Bangladesh	Total fish loss is estimated as 39,797mt and US$3.97 million using the prevalence data obtained from this study	54% price fall in slightly ulcerated table fish	
Lilley et al. (2002)	Epizootic ulcerative syndrome	2002, but use of old estimates	General	Based on 1992–95 data; semi-intensive and intensive carp production: national loss US$ 1,185,000. In extensive production: US$ 566,000. Losses due to lowered productivity may be of *greater significance* Reduced aquaculture and fisheries production can be demonstrated during times of serious outbreaks, although it cannot be positively determined that the disease was the factor that caused the decline.	75% price fall in EUS-affected locality	
McRae et al. (2002)	Disease condition	July–Aug 1999 –	South-western Bangladesh – prawn and carps	EUS average by farm 31.44$ and virus: 77.5$ Loss due to disease 7.6% of the profit (but not all of infectious nature)	An average of 5.8% of loss of income	Reports among the interviewed farmers: reduced price at markets increased their debt, reduced household income.
Faruk et al. (2004)	General fish disease	2004	Mymensingh, Comilla, Jessore, Natore and Dinajpur – carp polyculture	Average economic loss: 15% of production, Tk[b]20615/ha = US$344. The higher losses were found in Comilla (and 19.2% of production loss) and the lower in Natore (prod.loss 7.9%). Estimation of disease control (prevention + treatment) cost: Farmers of large category spent Tk3352/ha/year, medium: Tk2879/ha/year, small: Tk2485/ha/year. By district, It was more in Mymensingh (Tk3145/ha/year) and the lowest in Jessore (Tk 2242/ha/year)		
Faruk (2008)	Diverse aetiology	April 2004 to March 2005	Mymensingh District – catfish	Economic losses of approx. 3.6% of farmers' total yearly income from fish production due to illness, the cost varied with the size of the farm. Small-scale farms presented higher economic losses than large-scale farms.		
Dey et al. (2014)	Diverse aetiology	March 2012 to January 2013	Baors of Jessore, Sampling area covered 1352.63 ha, 71.87% of the total (Indian major carps and some exotic carp species)	In 2012, high prevalence of various diseases but 0.513% loss of production (=Tk0.7599 million)		
(Khan, n.d.)	Tilapia diseases	2014	Mymensingh (Gouripur, Muktagacha and Tarakanda), Jessore and Chandpur region.	Jessore- hatcheries and nurseries: 25–35% mortality rate. Mymensingh- hatchery owners: 10–15% fry losses Chandpur hatchery: 20–30% fry losses in the spawning season. Nursery –8–10% of fry losses Economic loss due to Tilapia diseases and mortality: Gouripur 17%, Muktagacha 22%, Jessore 24%, Chandpur 31% and 90% in Tarakanda		

(*continued on next page*)

Table 2 (*continued*)

Ref.[a]	Disease/ hazard/topic	Year(s) study focuses on	Area covered – studied species	Production losses	Price impact/Livelihood impact/Trade impact/Mitigation costs: for private sector/for public sector	Public Health impact and others
Begum and Alam (2002)	White Spot Syndrome Virus	2002	Khulna, Sathkhira		Trade impact ban on the importation of fishery products into European Union (EU) markets from Bangladesh imposed in 1997–1998, and the fall in price of 30–40% in the international market.	The price of land in the coastal area where shrimp is farmed became constant due to the negative impact of disease. At the beginning of shrimp culture, land cost Tk 10,000/bigha (US$1470/ha; 1US $ = Tk50.66). The price then jumped to Tk30,000-40,000/bigha (US$4410–5880/ha)
Mazid and Banu (2002)	White Spot Syndrome Virus	2002	shrimp	Estimated damage due to disease was to affect 50–60% of the semi-intensive shrimp farms in Cox's Bazar in 1994, and estimated monetary losses of Tk500 m (US$10 m) (M.S. Islam, unpublished data). In another report, average financial loss per affected farm was estimated as high as US$832/year for extensive and US$3928/year for semi-intensive farms (Chowdhury 1997)	Trade: 44.4% production loss in 1996 led to a reduction in foreign income of 42.3% from shrimp exports (DoF; Siriwardena 1997) Livelihood: It was estimated that the shrimp culture industry provided direct employment to some 350,000 persons, engaged in fry collection and transportation, nursery and grow-out operations, and handling and processing. Disease outbreaks in fish and shrimp culture systems were described to have a *great impact* on low-income groups	
(S. M. N. Alam et al. (2007)	White Spot Syndrome Virus	January to August 2002	Munshiganj Union, Shyamnagar Upazila of Satkhira District	Average production cost/kg of shrimp Tk424.12 (US $7.25). Average farm gate selling price of shrimp was Tk282.55/kg (US$4.83/kg). Negative profit of Tk145.08 (US$2.48) for shrimp farmers in the study area. The return to total cost of P. monodon was a negative profit (Tk0.78).		
Chowdhury et al. (2010)	White Spot Syndrome Virus	March 2007 to February 2008	Greather Khulna region, Rampal, Mongla and Shayamnagar	Combined system resulted in better return, incurs in less risk and it appears to be a more sustainable business in all the aspects, included economically.		It explains how combined systems would be beneficial in the food security impact, although it does not measure it.
Karim et al. (2012)	White Spot Syndrome Virus	2006	Bagerhat Khulna and Shatkhira	Incidence of disease is higher in traditional systems due to the lack of biosecurity. Highly technologically developed systems are more profitable only in non-disease situation, but are the most vulnerable to the impact of disease. The best BCR in situation of disease is reported in intermediately improved systems, followed by traditional systems.		
Debnath et al. (2014)	White Spot Syndrome Virus	March-August, 2010	Cox's Bazar			Association between WSSV prevalence and reproductive performance according to the depth zone (shallow or deep areas of the coast). WSSV negative broods were found to achieve higher hatching rate than positive ($p < 0.000$)) regardless of the zone. The study shows an inter-correlation between depth zone, brood size and incidence of the virus.

[a] Studies in this table are divided between studies of finfish and shrimp. In each group, references are sorted by year and alphabetically by author.
[b] Tk = Bangladeshi Taka.

2001 caused a decrease in production yields that led to market price fluctuations and a reduction in profitability (S. M. N. Alam et al., 2007). Karim et al. (2012) reported that the lowest percentage of shrimp crop loss was found in a modified traditional system (21%) followed by the traditional system (29%) and the more advanced modified system (33%) while highly controlled systems suffered the highest losses (54%). The best net returns in the absence of disease were presented by the controlled system (USD 3145/ha and year) while it also suffered the highest losses in a situation of disease (USD −1350/ha and year). The authors argued that a principal cause of the differences in profitability between systems was the diversification of production (polyculture), which provides additional returns. Contrary to that, Chowdhury et al. (2010) showed that differences in return from only-shrimp production systems and rice-shrimp productive systems were insignificant. They also reported that 21% of only-shrimp and 16% of rice-shrimp farms were operating at a net economic loss. Begum and Alam (2002) described how the once raising land price of the South West shrimp production areas stagnated due to disease impact and lower production and profitability and reported market price effects caused by a trade ban imposed by the EU.

In terms of methodology, studies until 2002 presented primary reports of impact. In general, studies referring to finfish production seemed to rely more on average estimates and used a less varied range of methods to evaluate the economic performance compared to studies in the shrimp sector. Mortality rates were often given and a few studies provided an approximate estimate of production losses. Studies on shrimp disease were broader and more detailed. Notably, Alam et al. (2007) estimated values of sales of the different commodities of shrimp farms, gross return, gross margin, net return and the benefit-cost ratio of the systems considered for disease affected and non-affected farms. Chowdhury et al. (2010) presented an approach to evaluate the sustainability of the production systems by developing an index, the Production Sustainability Index, that aims to capture social, environmental and profitability information. It represents the productive trend over the last decade taking into account the respondents that indicate an increasing, a constant and a decreasing yield, multiplying them by different factors. No study presented wider reaching estimates such as the impact on nutrition or food security, even though disease impact in smallholder farmers was described and most studies acknowledged the importance of these commodities for the food security of the country. Similarly, the impact on livelihoods received limited attention. Mitigation costs for both animal and public health were not included in any of the studies. Other impacts such as biodiversity loss were mentioned in relation to climate change, but not included quantitatively.

3.2. Interviews

A total of 23 interviews were conducted with 28 people in different capacities from private and public institutions as well as NGOs (Table 3) Seventeen of the interviews were carried out in face-to-face interviews in Dhaka in October 2015, and 6 interviews were conducted by Skype. In addition, one of the interviews was organised as a workshop with the active participation of six aquaculture professionals working in private sector companies. Another interview was conducted as a group interview with 10 professionals representing research, development, public and private sector (including a government officer). Interviews and discussions were facilitated by a researcher from WorldFish and the interviewer. In the workshop interview, time was given to participants to discuss the answers between them. different levels of participation and engagement were observed, but all participants were given the opportunity to get involved. The group interview was considered as one group, as it was mainly responded by one person with scattered participation from the other attendants.

3.2.1. Governance: institutions involved, hierarchy, legislation, criteria used

A multitude of public and private institutions take decisions on animal health management. However, participants reported that there was no legislation regulating infectious disease control in aquaculture products in Bangladesh and only three interviewees were fully involved in animal health projects. The rest had some knowledge about aquatic animal health, but their primary duties addressed other aspects of fish production.

According to respondents, the fish sector in Bangladesh is structured as follows: The Ministry of Fisheries and Livestock (MoFL) is the highest authority with administrative control over aquaculture in Bangladesh. It delegates to the Department of Fisheries (DoF) and the Department of Livestock Services responsibilities for development, management and conservation. A recurring observation among participants was the lack of regulations addressing not only control of infectious diseases but also aquatic animal health problems. The Department of Fisheries provides the extension services, which consist of one extension officer in each sub-district or Upazila (total of 493). When required, they collect information, but this group mainly has an administrative role. Moreover, Bangladesh Fisheries Research Institute (BFRI) in collaboration with universities such as the Bangladesh Agricultural University in Mymensingh, perform aquatic animal health tasks aside from their duties. An “Aquatic Animal Disease Diagnostics and Surveillance” system has been created but no extra resources have been allocated to carry out the tasks. Interviewed researchers pointed out that usually they take advantage of MSc and PhD projects to investigate reported occurrence of disease. In some cases, farmers ask BFRI for support in the investigation of disease. However, it was agreed among all respondents that when disease occurs, farmers call private companies (such as pharmaceutical or feed companies) that usually provide them with inputs (e.g. seed, feed and health products) and advice.

The most common scenario described is that private companies advise on treatment or management procedures in the case of aquaculture health problems, and unless the problem is bigger or farmers ask for help from BFRI or WorldFish scientists, the information of the outbreak or occurrence of disease will rarely reach the extension officers. Most diseases are macroscopically diagnosed, and further facilities are not available unless the samples reach BFRI laboratories and Bangladesh Agricultural University. It was described that private companies do not offer diagnostic facilities beyond macroscopy (visual inspection without the use of microscopes), and that the diagnosis will depend on the training of the aquaculture professional. Information exchange on animal health between organisations and information flows between public sector organisations and extension officers were reported to be limited. However, export commodities showed a different picture, as certain quality standards in the shrimp and fish value chain need to be complied with, based on ISO norms and HACCP. Private businesses that export to the European Union are audited by European inspectors, from the European Commission (in particular from the Food and Veterinary Office), in order to be recognised as a qualified exporter. The Department of Fisheries seems to put emphasis on the enforcement of these standards with the main aim to control residues in the products as well as to evaluate the processes and hygiene. It was reported that “There are national surveillance and monitoring programmes as well as recognised laboratories for doing testing for nitrofurans and chloramphenicol. The exporters have traceability systems in place, as an insured policy and it is only traced back to the collector centre” and “Extra requirements have been imposed to the country of Bangladesh due to negative past practices”. Accordingly, the Department of Fisheries liaises with the Directorate General of Drug Administration (DGDA), the regulatory body in charge of the quality control of human and veterinary drugs, under the Ministry of Health and Family Affair (MHFA), as main implementers of the “*Guidelines for the Control of Aquaculture Medicinal Products – AMPs*” (MoFL, 2015). While DoF is in charge of the health management advice, field monitoring of drugs and users (according to the Good Aquaculture Practices), as well as information and training, the Directorate General of Drug Administration regulates the processes. These include the

Table 3
List of people interviewed by organisation and role.

Organisation	Number of people	Number of interviews	Role(s)	Area of work
WorldFish – Research and development organisation	7	7	Scientists and project leaders, mostly not related to animal health	Planning, implementation, advisors, analysis
FAO[a] and CVASU[b] – International agency and associated university group	2	2	2 taking part in influenza projects, 2 of them in food safety and value chains	Planning, implementation, analysis, communication of surveillance
BFRI[c] and BAU[d] – Government research institute – fisheries, and associated university group	5	5	2 PhD students, 2 senior researchers (authors of some articles and involved in Aquatic Animal Disease Diagnostics and Surveillance)	Advisor/responsible of fisheries research
DoF[e] – Government – fisheries	2	1	Director and Deputy Director	Planning, development, extension and training,
DLS[f] – Government – livestock – epidemiology	1	1	Scientist in epidemiology unit	Analysis and communication of surveillance – research and training
BRAC Enterprises Limited	2	1	General manager, manager DGM, manager	Enterprise and NGO
Winrock International – Non-profit organisation	1 group[g]	1	General director, country representatives	Resource allocation, planning
Private sector workshop	6	1	Professionals, representatives of national and international animal health companies	50% answered to implement and analyse aspects related to aquatic animal health. The other 50% answered to be involved in all the processes but the analysis, in awareness building and training
AIDA[h] – NGO	1	1	Professional in the area of development	Planning, implementation, analysis
Solidaridad Network – NGO	1	1	Professional in the area of development	Planning, implementation, analysis
Producers	2	2		

[a] Food and Agriculture Organization of the United Nations.
[b] Chittagong Veterinary and Animal Sciences University.
[c] Bangladesh Fisheries Research Institute.
[d] Bangladesh Agricultural University.
[e] Department of Fisheries.
[f] Department of Livestock Services.
[g] One group of 10 people participated, mainly led by one person and scattered participation from the rest.
[h] Ayuda, Intercambio y Desarrollo.

registration of drugs, control of manufacturers, issuing of licences and control of the AMPs value chain actors (warehouses and wholesalers). The Directorate General is also involved in the guidelines implementation by providing information and training to value chain actors. Thus, more emphasis from the public sector seems to be placed on enforcing certain legislations (mainly food safety orientated) that will impact international trade and support the national economy. Even though there are limited resources for fish disease diagnostics, facilities are in place for export oriented products. Additionally, it is stated that in Bangladesh there have not been any studies evaluating the cost of food safety. It is assumed that private companies and government keep internal records for the audits to reach the standards, but no information about this surveillance system or evaluation could be obtained. Moreover, all the stakeholders acknowledged the poor availability and accessibility of data at all levels due to "poor systems" and they admitted the lack of importance attributed to diligent record keeping.

All respondents highlighted that extension services are insufficient to reach all farms, that they should be more pro-active, and have more knowledge and training on aquatic animal health. There is no possibility of reliable diagnosis most of the times and importantly, farmers lack training. Farmers that were beneficiaries of development projects stated in focus group discussions (FGD) that in the last 10–15 years they never received training in management or marketing. In addition, respondents from two organisations stated that health in aquaculture was in general neglected, since "fish are under the water, you cannot see them" and that they do not have the same status as livestock for decision makers, "fish is just fish". However, in the group interview held with the private sector, participants demonstrated awareness of the negative impact of use of chemicals and declared that currently the government bans and penalises the use of certain drugs. Some emphasised the need of prevention over treatment and researchers from two organisations argued that there is lack of evidence of the efficacy of those treatments, and knowledge about management of the ponds should be prioritised.

Despite the wide network and links among aquaculture professionals and collaborations for development projects, lack of communication, disconnection and weak bonds were often evident. Whilst researchers, universities and development institutions showed more robust relationships, engagement among the research community and private sector, depositary of most of the advising tasks in the farms, was perceived as poor or inexistent. Finally, all the respondents concurred about the importance of donor institutions, as most of the initiatives regarding aquatic animal health from a research or development point of view depended on them.

3.2.2. Perception of the impact of infectious disease and wider factors

Respondents expressed their views about the importance and impact of infectious disease and understanding of the bigger picture of the production systems. As a result, a wide variety of perceptions were recorded and whereas all respondents named WSSV as a threat in shrimp production systems, some dismissed the impact of infectious diseases on finfish compared to other problems, such as quality seed and feed and market price fluctuations. Nevertheless, some people working in direct contact with farmers stated that disease was a recurrent concern in FGD with farmers. In addition, several interviewees in research, government and NGOs expressed concerns about the impact of intensification on the emergence of disease problems and the resulting need for effective animal health management in the light of the rising demand for fish. Another important concern was the effect of climate change, in particular how rising sea temperatures could be enhancing viral reproduction. Participants described that changes in seasonality patterns affected the epidemiology of different pathogens and the water quality. Moreover, the use of pesticides in agriculture and their effects on aquatic populations were named. Market volatility and high inputs prices compared to the low selling prices were described as important constraints for farmers.

3.2.3. Usefulness of impact studies

Regarding the usefulness of impact studies in supporting decision making regarding animal health and the perception of the impact, all respondent institutions agreed that there is insufficient capacity and knowledge in terms of aquatic animal health. Surveillance conducted is not systematic and studies are produced on an ad hoc basis. These activities were only performed by BFRI, that also acts as advisory body for MoFL and DoF, other academic institutions conducting research and development initiatives. The respondents seemed not familiar with impact studies and were not used to base their decisions on impact in an evidence-based manner. One respondent from a development organisation highlighted the need for and use of these studies, corroborating that while in other countries there have been studies about the economic cost of food safety, in Bangladesh they are not existent and studies on animal health topics are very scarce. Several respondents reported that they were aware of certain diseases being a problem and also had an appreciation of their severity – sometimes even supported by (unpublished) figures. In general, people seemed to be more focused on problem solving than assessing the presence of disease, as expressed in this quote: "we know that diseases and mortality are a problem that it needs to be solved …. solving it is more important than measuring it". However, opinions differed on the importance of infectious diseases in the sector.

There was a variation in the management of data and evaluation of processes to inform resource allocation. NGOs described in detail what processes are needed to manage, analyse and present data, as shown in this quote: "we need to present data about the project performance, it is essential for the organisation, for evaluators and donors. In every conducted project, there is a minimum of information to present to the evaluators. There must be always baseline data, end line data and information of certain indicators. In addition, according to the donor they might be asked for a logical framework approach and results-based management, and according to the quantity of funds, they need to pass an external evaluation. The organisation is always audited internally or externally. Finally, technical reports need to be developed, detailing activities and outcomes as the indicators that inform about the achievement of the goals". However, the results are usually not publicly available. Other organisations only stated that "they use profitability analysis, evaluating the performance of the enterprise, but it is for internal use".

When asked about the sources of information, whether they have access to records or a surveillance system, some replied that "these things are known" implying the flow of informal information and updates among the stakeholders. Others have contact with farms and gather information through this route or use focus group discussions. Researchers acknowledged the need of strengthening the communication between stakeholders and the sharing of information. However, the overriding perspective among many respondents from all groups was that investing in actions is more important and that they are already aware of the problem and do not need impact studies. Professionals from private companies discussed that in their decision making regarding advice on which treatment or management to suggest, guidelines and training is offered by their companies and added to their expertise; that is what drives decisions.

4. Discussion

This study aimed to gain an understanding of the disease impact on key aquaculture systems in Bangladesh, the methods used to estimate disease impact and the usefulness of such studies to decision-makers to guide policy development and planning. To achieve this, a literature review was conducted and diverse stakeholders were interviewed.

Given the importance of the aquaculture sector in Bangladesh, there was a relatively low number of disease impact studies. Among the 15 publications reviewed, differences in impact were found across species determined by the nature of the pathogen, disease occurrence (i.e.

epidemic vs. endemic), and market patterns (export vs. non-export commodity). Because of the low number of studies found, no single predominating impact assessment method could be identified, but the estimation of production losses (using different approaches) was described in various studies. Trade impacts were only reported for shrimp due to the exports ban related to lack of quality or presence or residues (Cato and Lima dos Santos, 1998). None of the studies presented wider reaching estimates such as the impact on nutrition or food security, even though disease impact in smallholder farmers was described and most studies acknowledged the importance of these commodities for the food security of the country.

Due to the low number of studies available and differences in their scope and methodologies, it was not possible to identify top-ranking disease constraints. Nevertheless, the studies reviewed clearly demonstrated that infectious diseases cause a perceptible impact in aquaculture production in Bangladesh. Studies identified on disease impact in shrimp addressed the impact of one sole pathogen, WSSV, whereas reports about finfish disease generally showed the impact of the disease status as well as an evolution over time. Accordingly, disease in finfish aquaculture was more often attributed to multiple aetiologies (infectious and non-infectious) which often were not or only partially ascertained. Nonetheless, EUS seemed to emerge as the pre-dominant hazard, causing particularly large outbreaks until approximately the years 1998–99. In more recent years, the existence of the EUS was still described, but the economic impact figures were lower compared to previous estimates thanks to lower rates of infection (Dey et al., 2014; Faruk et al., 2004). Interviewees hypothesised that the magnitude of losses has decreased due to changing production practices and/or immunology or pathogen-host interactions. However, scientific studies to understand the epidemiology in detail are lacking. Impact studies for other clinical syndromes reported by interviewees as important threats, such as tail rot, gill rot, fin rot or dropsy and parasitic diseases were not found. These are clinical syndromes characterised by a multifactorial origin often attributed to poor aquatic health management. In addition, the low level of development of finfish systems, as low resources invested in diagnostic facilities and human capacity is a crucial factor for the occurrence of these syndromes. Remarkably, substantial production losses were reported for finfish diseases in several studies; one study reported production losses of up to 90% in certain areas in tilapia production (Khan, n.d.). Livelihood impacts were also estimated with one study reporting a decrease of 18.5% in total average yearly income from carp production (Brown and Brooks, 2002) and another reporting a decrease of 3.6% in livelihood from catfish production (Faruk, 2008). The study also highlighted the lack of disease awareness and knowledge of the farmers, and that situations of chronic mortality and poor growth due to mortality often remain unrecognised.

Studies on WSSV in shrimp seemed to be triggered by the impact on the national economy. In general, studies about the shrimp sector were published in the last decade, and used questionnaires to collect information about the disease incidence, production characteristics, economic performance and information about different factors. Given that shrimp generates important export revenues (it is the second most important export commodity after garment), any disease that causes losses at a large scale can have a substantial negative impact on the economy. The foreign exchange obtained through these exports allows import of industrial capital that eventually can lead to economic growth and the repayment of external debit. In addition, the sector creates jobs and contributes to the development of infrastructure (Pollard, 2010). Consequently, several economic studies on disease impact in shrimps addressed societal and trade impacts in addition to the economic profitability at the farm level and discussed regulatory frameworks relating to quality control and export.

The review showed that disease impact is a serious constraint to profitability in aquaculture in Bangladesh. Given the substantial increase in domestic tilapia and *Pangasius* production in the past decade and the importance of finfish for food security, more specific studies to estimate not only wider-reaching disease impacts but also a broader range of hazards is recommended. Such information is a necessary baseline for ex-ante assessment of the economic profitability of intervention strategies for disease management and thereby inform resource allocation (McInerney, 1996). An important limiting factor for the generation of impact studies may be the lack of data on disease occurrence and the biological effects of the disease – both important prerequisites to assess the consequences of disease. This study shows that the knowledge and training of farmers and professionals of aquaculture in aquatic animal health is poor. In addition, diagnostics and surveillance capacity is limited to research groups who commonly face funding and resource constraints. As a result, studies on prevalence are scant. This scenario was reported in studies a decade ago and does not seem to have improved (Brown and Brooks, 2002; Faruk, 2008). Conversations with stakeholders showed that aquaculture surveillance is limited to residues in export-oriented products, mostly shrimp. This is in stark contrast to for example the poultry sector, where surveillance systems were greatly improved or developed following the avian influenza outbreak. The outbreak of avian influenza highlighted the need for effective outbreak response and skilled veterinary and livestock production experts (GoB, 2012) causing a rise in disease awareness and prompting public and private stakeholders to invest in terrestrial livestock disease management. Since then, the FAO in collaboration with the Department of Livestock Services (DLS) and Universities promoted improved surveillance and monitoring systems with a gradual transfer of the responsibility to domestic stakeholders over time (i.e. DLS and universities). In aquaculture on the other hand, public disease management structures are deemed insufficient and only represented by poor extension services (Faruk et al., 2004; Faruk, 2008). The reported lack of investment into surveillance capacity and diagnostic facilities in finfish may be driven by a perception that fish receives less attention than other species, because it is “under the water, you cannot see them”. Extension officers were described by interviewees to lack training and knowledge about animal health and management. Moreover, farmers seem to rely rarely on these services, indeed one study showed that only 10% ask for these services (Faruk, 2008). In comparison, in the poultry sector in Bangladesh, extension officers are regarded as experts that provide good quality services, to the extent that small commercial farmers demand their services outside of their civil servant duties, covering these extra services (personal communication). In the absence of a similar service provision in the aquaculture sector, a system has emerged where producers receive services from private companies or private dealers that provide them with inputs and chemicals. Studies have reported that producers are hassled by the pharmaceutical companies to buy their products (Faruk, 2008). Thus, strengthening of the public animal health service provision could lead to improved capacity not only for disease management, but also data collection for surveillance. Further, better quality and more reliable public extension services in aquaculture may have a stronger positive impact if combined with activities to build the trust of producers in these advisors and raise awareness on the importance of aquatic health management. Farmers were previously reported to rely on other peers for information (Faruk, 2008), which shows their interest to learn. Their behaviour is also influenced by the one-time treatment solutions that private companies advisors offer, in contrast to the needed adoption of new practices or routines (personal communication). Consequently, clear messages on the effect of improved aquatic health management and value of surveillance. However, relevant evidence needs to be established first through thorough research. For the dissemination of these messages and to strengthen engagement of stakeholders in aquatic health management and surveillance, latest developments in information and communication technologies (ICT) will be beneficial.

While improved disease knowledge could inform disease impact studies, the relevance of these for decision-making remains limited given the current structures. The interviews with decision-makers clearly showed that decision-making processes rarely rely on disease

impact studies. Some organisations reported to conduct evaluations and profitability studies, but commonly these were for internal use only. Moreover, none of the respondents described systematic processes that would consider multiple criteria (e.g. including economic benefits or food security) such as multi-criteria decision-analysis. This may be partly due to a lack of reliable surveillance information on disease prevalence, as well as lack of data on geographical and temporal distribution patterns and associated economic impact. However, there also seemed to be a perception among some stakeholders that such studies are not necessary. Some respondents claimed that improved impact information is not needed as "such things are known" and resources should be spent into solving the problem instead of measuring it. This view contrasted the perspective held by other stakeholders which emphasised "the need of prioritising resources according to the impact of the different threats, for which evidence-based approaches and studies to establish the cost of interventions are essential". There was disagreement about the relevance of certain hazards thus implying that more accurate disease information may be helpful to prioritise diseases for investment.

However, improved surveillance data and economic impact studies can only have a true value if the information provided is used to inform decisions; i.e. an improvement in surveillance systems should be accompanied by communication pathways and processes to make systematic use of the information and improve animal health management. Despite the effort and the evidence shown by some studies, there are no national large scale projects to improve fish health. Moreover, country investment plans addressing agriculture, food security and nutrition, do not include aquatic health objectives (GoB et al., 2010). Nowadays, with the introduction of exotic species that have the potential to increase productivity, such as *Pangasius* and tilapia, new infectious diseases problems seem to be emerging (Faruk 2008; Faruk et al., 2004; Ali et al., 2013.), warranting improved disease management. However, national approaches are challenging due to a high population density in megacities, weak field services, bureaucracy and – in the case of fish production – limited human and institutional capacity. This complicates the improvement of market strategies, which was described as one of the key objectives for development projects. Another important point emerging in the interviews and supported by some reports and studies (Karim et al., 2006) is the weak relations between stakeholders, especially among researchers and private company stakeholders. Based on experiences from this study, the flow of information and relationship between private and public institutions should be strengthened in order to support surveillance and technology improvements. Similarly some studies showed the distrust of producers in the service of extension officers (Faruk, 2008).

Due to the diversity of decision-makers across the aquaculture sector and qualitative nature of the research, representation of the main institutions and decision-makers in the field was ensured by following a purposeful sampling approach. This was not a representative survey but a study to gain deeper understanding and insights into the decision-making processes and governance aspects. Accordingly, the group of producers was underrepresented, as only two interviews were conducted, compared to other decision makers that were the primary target group of this study. However, flows of information involving producers, their needs and other relevant issues, were captured by the different decision makers interviewed, who had extensive field experience and regularly engage with producers, namely researchers, government officers, scientific officers in development agencies, professionals at Non-Governmental Organisations and private sector professionals with advisory roles. Moreover, interviews were conducted in English, but it was not a selection criterion. The use of a non-native language could limit the access to information and participation from non-English speaker decision-makers, for example, limiting the participation of small producers. Based on the findings of this study, it seems advisable to conduct a follow-up survey to obtain quantitative information to better characterise different stakeholder groups, including the producers, to investigate their perceptions and practices. interview

In addition, given the scarcity of impact studies in aquaculture and the challenges for disease control, a comparison with another animal production sector is helpful to identify ways forward. The poultry systems for example has some parallels with the aquaculture system. Both sectors present similar characteristics, namely common sources of inputs, complex value chains with many actors involved, vulnerability to price volatility and market constraints, and common threats, such as infectious diseases. In addition, both contribute importantly to the livelihood, food security and the national economy. Impact studies in the poultry sector focused mainly on Avian Influenza, but were wider reaching in scope and methods taking into account production losses, ripple effects, public health impact and effects on neighbouring countries (Alam et al., 2008; Chakma and Rushton, 2008). Interviewed stakeholders of the poultry sector (data not shown) described that animal health systems are more advanced than in aquaculture with more knowledgeable extension officers and more systematic surveillance processes in place.

The findings of the study clearly point towards a need to improve aquaculture health management. Currently, decisions are not evidence-based but rather represent reactive responses and there is a lack of appropriate legislation and capacity for disease surveillance. A suitable entry point to strengthen aquaculture health management would be the development and delivery of educational materials to improve farmers' knowledge on sustainable management, fish health and diseases and diagnostics, and business management. Further, strengthened training of future and existing aquaculture professionals in responsible and sustainable animal health management will be crucial to enhance their animal health capacity and to contribute to disease surveillance. Moreover, training of producers and their advisors in aquatic health management would potentially increase the responsible use of antimicrobials, resp. reduce misuse, and thus in the long term increase the benefits of the resources invested.

Given the findings on the aquatic animal health services, a formal in-depth assessment using the OIE performance of veterinary service tool (PVS) (OIE, 2013) is advised to provide more insights on the gaps and specific areas that need investment. Based on the PVS assessment, aquatic health services can be meaningfully adjusted to fill the needs of producers. Moreover, PVS assessments have proved to be important to define national strategies on aquatic health management, for example developing a simple and practical disease management system that suits the needs of the country. Such an approach would change current practise of point-projects that characterise the current aquaculture management interventions in Bangladesh, by providing a basis for a more coherent research programme and investment in development and extension services while strengthening surveillance which complies with international standards. Investments related to a national strategy can be assessed by cost-benefit analysis that incorporates fixed and variable costs and assesses impact in the long term. Public sector resources to be invested in the aquaculture field currently seem to be limited. Consequently, engagement between private sector, research, government and development institutions needs to be formalised to facilitate long-term collaborations and investments that provide data and evidence needed to inform policy dialogue towards suitable legislation and policies that will improve flows of information between stakeholders. Eventually, this should translate into effective and sustainable national disease surveillance and aquaculture health service delivery programmes for producers.

5. Conclusions

This study provided insights into the impact of animal diseases in the aquaculture sector in Bangladesh. Even though there were only few impact studies available, it became evident that disease has substantial impacts and decision-making processes are not conducive to improve the aquatic animal health system.

Improved surveillance and diagnostic systems as well as more evidence on disease impact could inform the prioritisation of diseases and resource allocation for disease control in Bangladesh. Because many interventions in animal health are part of development projects and thus dependent on aid, interventions can rarely be sustained after project funding runs out. Long-term government investment to enhance animal health management could improve capacity and reduce vulnerability of the sector. To be able to allocate resources in an evidence-based manner, the generation of information on disease impact and economic efficiency is crucial. To achieve this, it will be imperative to implement solid, transparent and reliable surveillance and communication systems that foster participation and engagement across different stakeholder groups, as well as information exchange.

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